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AN APPLE STEM-TUMOR NOT CROWNGALL[1]

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There are many kinds of apple-tree outgrowths or stem deformities; some are due to winter injury, some to weak variety conditions, some trees have short internodes, others, swellings of internodes or nodes. The type referred to in this paper as stem-tumor is the outgrowth with masses of rootlike projections or, as it occurs on some varieties of apple trees, an outgrowth with a smooth or nearly smooth surface. The outgrowths vary in size from small warts (Pl. 2, A) to tumors 2 to 6 inches in diameter, though they project scarcely more than one-half inch beyond the surface of the stem (Pl. 1, C). On some trees the bark remains comparatively smooth and the tumors do not reach a breadth of more than two or three inches (Pl. 3, B); but usually the bark breaks and masses of aborted roots appear, giving a roughened budlike surface to the outgrowth. The tumors of the bud type increase in size readily and in time the bark may become black and rough and broken if the tree is a very susceptible one. This may extend along an entire limb (Pl. 2, C). The budlike type is the more common.

These tumors are similar in macroscopic details to tumors produced by artificial inoculation with pure cultures of *Bacterium tumefaciens*. Furthermore, crowngall and hairy-root are widely prevalent on apple trees. Accordingly, although some entomologists[2] have referred to infestation by woolly apple aphis as capable of resulting in galls or warty swellings on twigs, limbs or trunk of apple trees, nursery inspectors, nurserymen, orchardists, plant pathologists and entomologists have in general referred to this type of outgrowth as aerial crowngall. However, this so-called aerial crowngall, of which Plate 1, A, is a good representation, is seldom, if ever, caused by the crowngall organism under natural conditions.

Since 1906 the writer has been concerned with crowngall on various hosts and during this period the attempts to isolate *Bacterium tumefaciens* from apple stem-tumors always have been unsuccessful, but as the tumors resembled the hairy-root type of crowngall as it occurs on apple roots it was believed that the disease was a form of crowngall. In 1923 the writer began a more critical study of the disease.

Some of the material used was received from several different States, and some of it was collected near Washington by the writer, so that there was ample material in good live condition for the platings. Platings were made from tumors just starting to form, and in all stages of growth and development, the largest being 6 inches in diameter.

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[1] Received for publication Dec. 20, 1923.

[2] BAKER, A. C. THE WOOLLY APPLE APHIS. U. S. Dept. Agr. Rpt. 101, p. 34. 1915.
CONNOLD, Edward T. BRITISH VEGETABLE GALLS. p. 100. London. 1901.
ORMEROD, Eleanor A. HANDBOOK OF INSECTS INJURIOUS TO ORCHARD AND BUSH FRUITS WITH MEANS OF PREVENTION AND REMEDY. p. 1-6. London. 1898.
STEDMAN, J. M. THE WOOLLY-APHIS OF THE APPLE. *In* Mo. Agr. Exp. Sta. Bul. 35, p. 40. 1896.
THEOBALD, Fred. V. THE INSECT AND OTHER ALLIED PESTS OF ORCHARD, BUSH, AND HOTHOUSE FRUITS AND THEIR PREVENTION AND TREATMENT. p. 141-153. London. 1909.

During the year 1923, 378 plates were poured. These plates were made from 23 different lots of material and included 38 sets. Previous to 1923, during the years 1909 to 1922, inclusive, there were 120 plates poured from apple stem-tumors, 12 sets from 9 different lots of material. No single colony of *Bacterium tumefaciens* appeared. There were some fairly constant bacterial colonies closely resembling crowngall colonies which appeared on the plates and these were tried out in 1923 on Early Harvest apple trees, a variety known to be susceptible to this disease. The trees were inoculated in May in 138 young growing stems, using 8 different colonies; controls were held at the same time and the inoculations were made in two orchards 18 miles apart. The following greenhouse plants, known to be susceptible to *Bact. tumefaciens*, were also inoculated with these 8 colonies: 30 Paris daisies, 31 young tomato plants, 16 Ricinus, 12 Bryophyllums, 5 tobacco plants and 6 geraniums. The results with these plants were all negative.

In the case of the apple trees under observation, swellings occurred in the axils of leaves of branches where there were neither inoculations nor control pricks. These swellings were small; even as late as October they were only 3 mm. to 1 cm. in diameter. Five swellings which occurred on the main stem of a young tree were much larger; these varied from 1 to 2½ cm. in diameter. The large outgrowths had the typical budlike projections of apple stem-tumor. These places were not inoculated nor were any places on the main stem of the tree inoculated. The only stimulating agent present in October which might be held responsible was the woolly apple aphis (*Erisoma lanigera* Hausmann) a colony of which was on each of these swellings. The tumors had been noted in July when they were smaller, and the aphis was also on them at that time. These tumors were so fresh and soft that the writer, thinking it might be a natural infection of crowngall, cut off portions of two of them expecting to isolate the crowngall organism very readily from these pieces. It could not be done.

Woolly aphids were in the axils of the leaves where axil swellings occurred (Pl. 3, A). The inoculated places were carefully examined and in all of the 138 inoculated stems there were only three outgrowths. These three places were in the axils of leaves and were covered with woolly aphids. Some of the small axil swellings on these Early Harvest apple trees were cut off, and also pieces of the large stem-tumors, a second time. Platings were made from both lots but neither the crowngall nor any other constant organism appeared on the plates.

In an orchard where stem-tumors were quite prevalent 44 trees were examined at the roots and woolly aphis root galls found on 34 of them; 32 of these rootgalled trees had stem-tumors, and only one tree was found with stem-tumors which did not also have the aphis rootgalls. On the roots of one of the trees most severely affected with stem-tumor the woolly aphis was present in great numbers and had produced root-tumors (Pl. 3, C). The same insects were present on the branches also and were abundant on the stem-tumors (Pl. 3, D). No crowngall was found on any of the trees.

Not all varieties of apple trees appear to be subject to these stem-tumors. The character of the soil and cultivation may have much to do with this, but some varieties, as the Early Harvest, seem susceptible under any conditions. Very susceptible varieties which have come under the observation of the writer are the following: Early Harvest, Wagoner,

Martin, Buckskin, Grimes, Ben Davis, Barnes' Best, Ensee. There were 10 varieties in an orchard examined which were less susceptible than the above named in varying degrees. All had woolly aphis rootgalls. The stem-tumors varied in size and number (Pl. 2, B and C) and on some trees there were indications that the tumors had kept on developing for some years; then some change in conditions took place and the newer branches were clean, since few or no tumors had formed during the last years. Four apple varieties in this orchard, Titavka, Loy, Bethlemite and Van Hoy, had no stem- or root-tumors and did not seem susceptible. The first three varieties had no woolly aphids on them anywhere. Although Van Hoy had some of the woolly aphids on the young twigs there were no swellings.

In a young orchard consisting of 58 apple trees, two of which were the Early Harvest variety, these two were the only ones with the woolly apple aphis on the stems and the only ones with stem-tumors.

Other varieties, such as the Chenango, Spitzenberg and King, affected with stem-tumors, were received from various parts of the United States.

A bad feature of the numerous stem-tumors on apple trees is the opportunity it provides for secondary organisms to get into the stem and ultimately cause more damage than the stem-tumor itself. The tumors are composed partly of soft cortex tissue which wood-invading insects can feed on and get through into the deeper portions of the stem, continuing their work of invasion throughout the year and forming great holes. The movement of sap is, of course, interfered with, which in turn affects the whole life processes of the tree. The breaks in the surface of the bark where the tumors push through likewise offer an entrance for the pear-blight organism, *Bacillus amylovorus*, which also causes greater damage than the stem-tumor (Pl. 2, D).

From the report of the results of Dr. J. J. Taubenhaus' work [3] with apple stem-tumor, it seems that *Bacterium tumefaciens* may occasionally cause stem-tumor on apple tree perhaps similar in appearance but of different origin from that described in this paper.

It is theoretically possible for *Bacterium tumefaciens* to produce tumors naturally on apple stems as well as on the crown and roots, for galls have been produced artificially by inoculating apple stems with *Bacterium tumefaciens* (Pl. 1, B). So far as the writer's observation goes, this organism confines its work in nature to the production of galls and hairy-roots on both crown and roots of apple trees. The cases of apple stem-tumor from various parts of the United States examined by the writer did not contain *Bact. tumefaciens* in a single instance.

CONCLUSIONS

Outgrowths on stems of apple trees herein described, and heretofore generally believed to be due to infection by *Bacterium tumefaciens*, the organism producing typical crowngall, are not secondary outgrowths from tumor strands nor are they primary infections of the crowngall organism. Although such conditions have not been observed by the writer, it is possible that in some regions there may be aerial tumors for which the crowngall organism is responsible.

[3] ADAMS, J. F. DISEASES OF FRUIT AND NUT CROPS IN THE UNITED STATES IN 1922. U. S. Dept. Agr. Bur. Plant Indus. Plant Disease Bul., Sup. 28, p. 308. 1923. (Mimeographed.)

The root projections on the stem-tumors carrying darkened and usually infected tissue deep into the tumors, and the hard woody nature of the outgrowths themselves, make isolations difficult. When *Bacterium tumefaciens* did not appear on the isolation plates, it was thought due to the dry or old condition of the material used, and it was not until 1923, when young, tender stem-tumors were studied along with older tumors, that the conclusions given in this paper were reached.

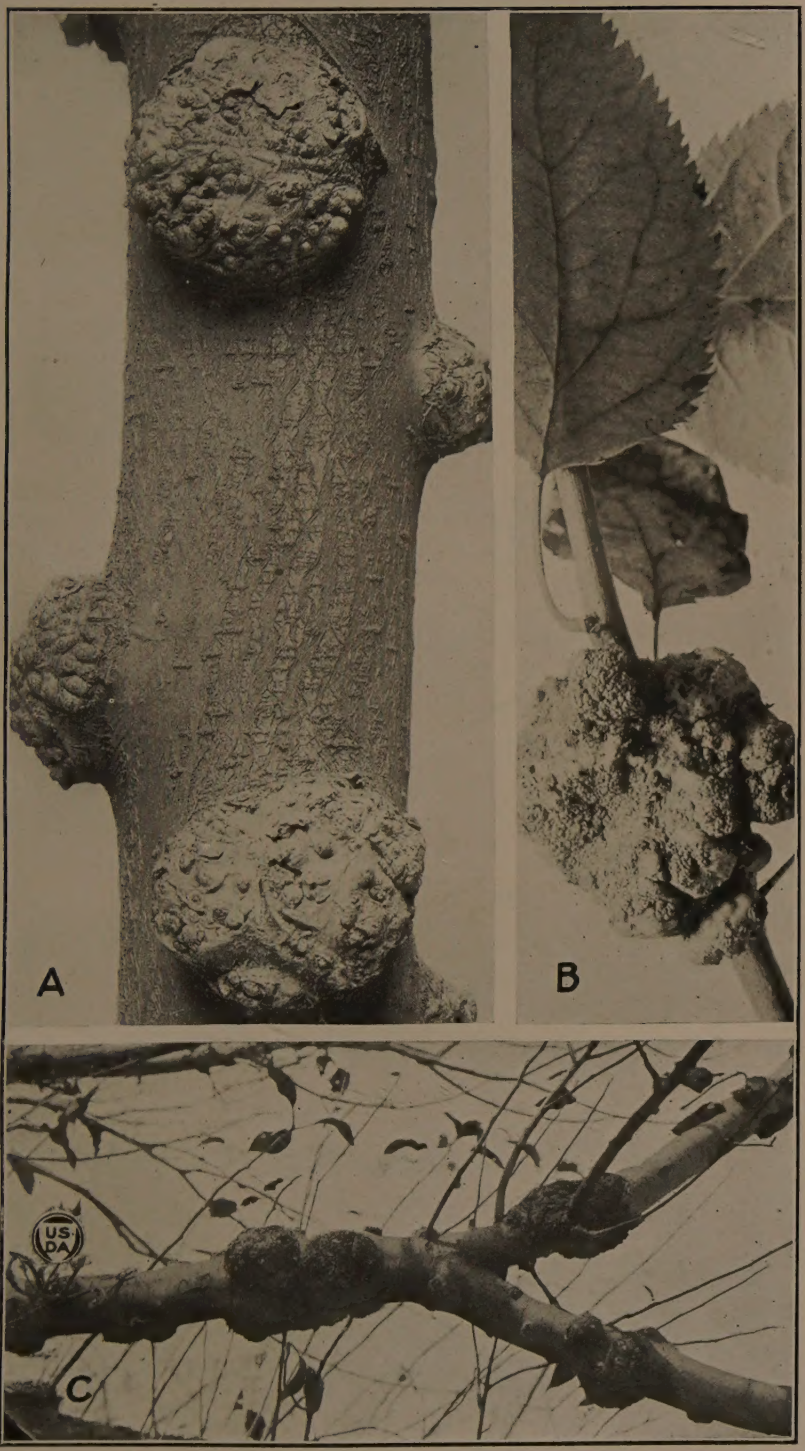
Whether or not the woolly apple aphis is the primary cause of the stem-tumors on mature apple stems herein described has not been within the scope of this investigation. There is a possibility, of course, that an organism may be transmitted by the aphids into the stems of apple trees—an organism which undergoes a change through insect transmission and which on that account does not retain its ability to infect after it has been isolated. This might explain the appearance on agar plates of colonies isolated from apple stem-tumor which at first so strikingly resemble the crowngall colonies, but lose this resemblance when cultured artificially and which also fail to infect when inoculated into apple trees and other plants susceptible to *Bacterium tumefaciens*. Had crowngall-infected apple trees been in the neighborhood of the apple trees affected by stem-tumor, the writer would be inclined to give attention to this possibility. But she found none. It seems, therefore, that *Bact. tumefaciens* is eliminated from the consideration.

PLATE 1

A.—Stem-tumor of apple tree from West Virginia. Natural size. Photographed April 22, 1923. No crowngall organism could be isolated from these tumors.

B.—Crowngall on apple stem produced by inoculating with *Bact. tumefaciens* (peach strain). Inoculated March 11, 1908. Photographed August 10, 1908; three-fourths natural size.

C.—Old and young stem-tumors on Wagoner apple tree, Virginia; one-fifth natural size.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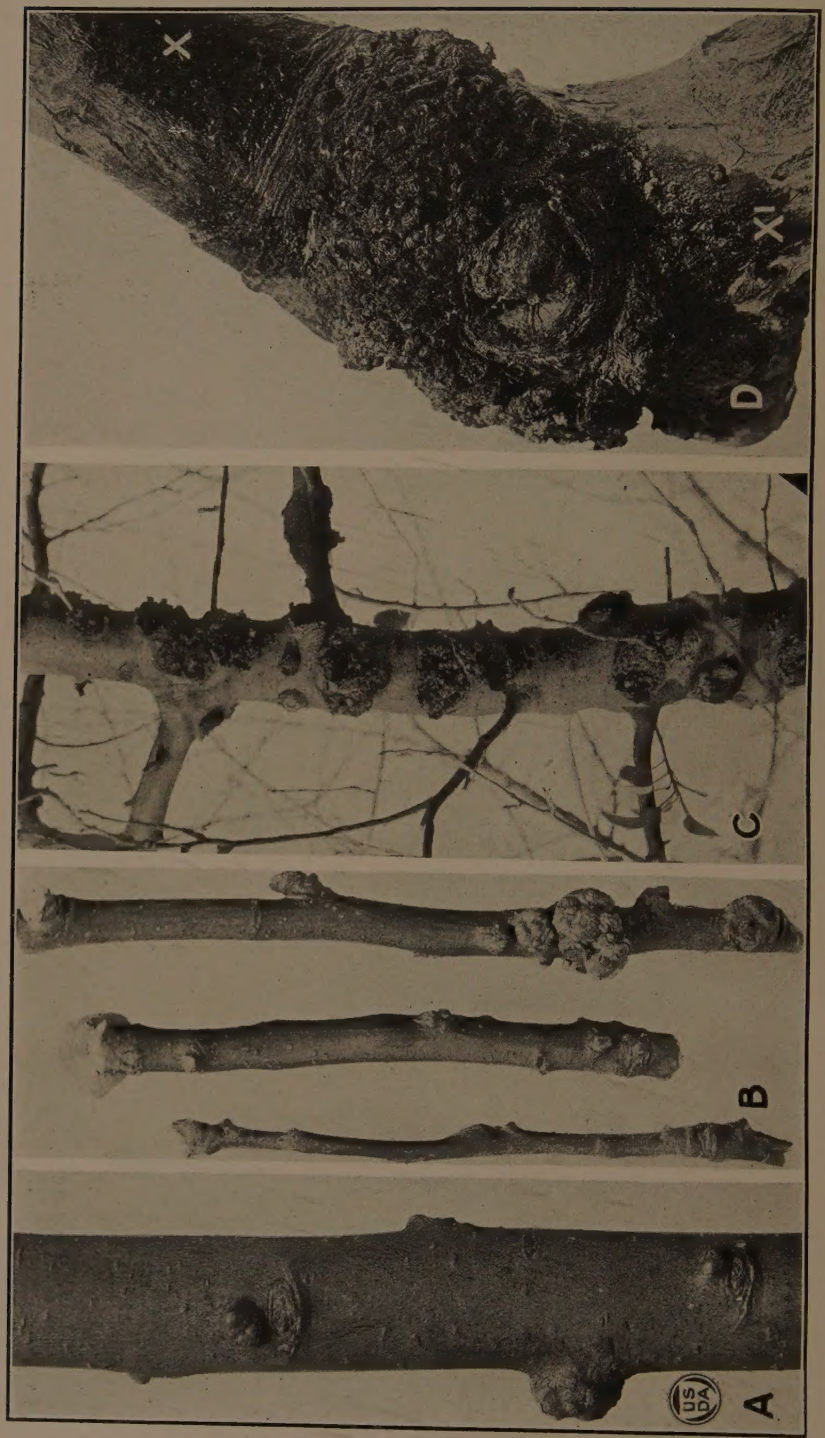
X
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PLATE 2

A.—Early stage of apple stem-tumor on Chenango Strawberry apple tree, West Virginia; natural size.

B.—Young stages of stem-tumor on Buckskin apple tree. The three pieces show three different years' growth of tumors on the same stem. Natural size. Plated from the largest outgrowth, but no crowngall organism was present.

C.—Older stage of stem-tumor on Buckskin apple tree, showing masses of aborted roots; one-fifth natural size. Same tree as B.

D.—Old stem-tumor on Spitzenberg apple tree from Oregon showing pear blight at *X* and *X'* as a secondary disease. Natural size.

PLATE 3

A.—Beginning of apple stem-tumor at *X*, and *X'*. Woolly apple aphis abundant at these places. Early Harvest apple tree, Maryland.

B.—Type of stem-tumor on Martin tree, which shows few or no masses of aborted roots. At *X* a few are ready to burst through the bark. Platings were made from tumor *X*. No crowngall organism was present. Woolly apple aphids were on these tumors; one-third natural size.

C.—Woolly apple aphis *root* galls on Buckskin apple tree; natural size. Same tree from which stems B and C of Plate 2 were taken.

D.—Early stage of apple stem-tumor on Buckskin apple tree from Virginia. ×5. Negative platings were made from these also. Note presence of woolly apple aphis.

X
X
X
A
B
X
C
USDA
D